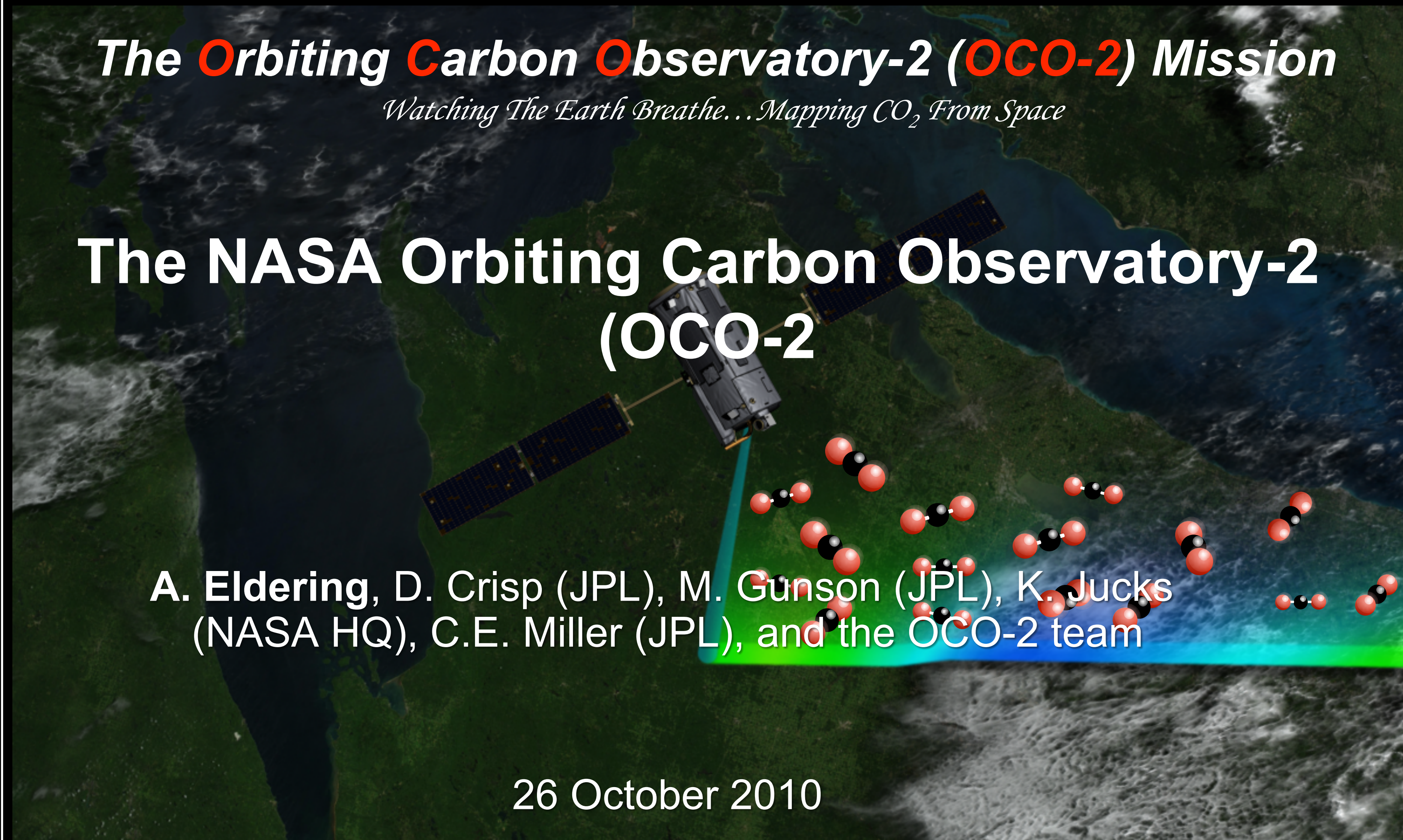


The Orbiting Carbon Observatory-2 (OCO-2) Mission

Watching The Earth Breathe…Mapping CO_2 From Space

The NASA Orbiting Carbon Observatory-2 (OCO-2)

A. Eldering, D. Crisp (JPL), M. Gunson (JPL), K. Jucks (NASA HQ), C.E. Miller (JPL), and the OCO-2 team

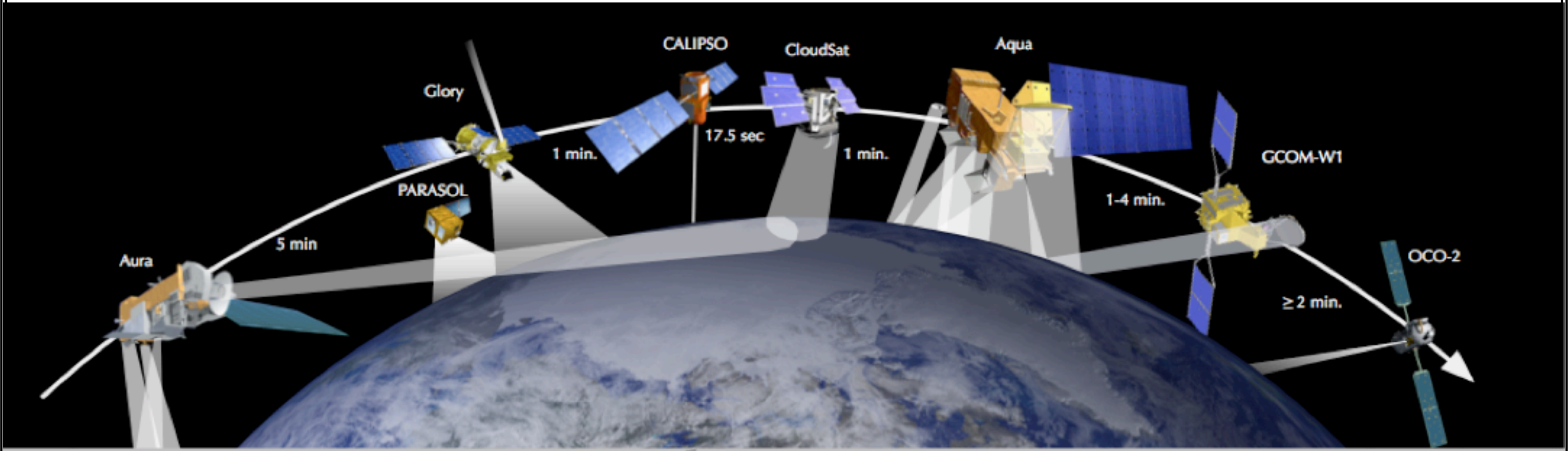
26 October 2010

OCO-2: The Future Lead of the A-Train Constellation

Jet Propulsion Laboratory
California Institute of Technology

The Orbiting Carbon Observatory - 2 (OCO-2)

Watching The Earth Breathe…Mapping CO2 From Space



- OCO-2 will "lead" the A-Train in the slot just ahead of GCOM-W1
- NASA's Orbiting Carbon Observatory (OCO-2) is designed to return space-based measurements of atmospheric carbon dioxide (CO_2) with the sensitivity, accuracy and sampling density needed to quantify regional scale carbon sources and sinks and characterize their variability.

OCO-2 Mission Architecture

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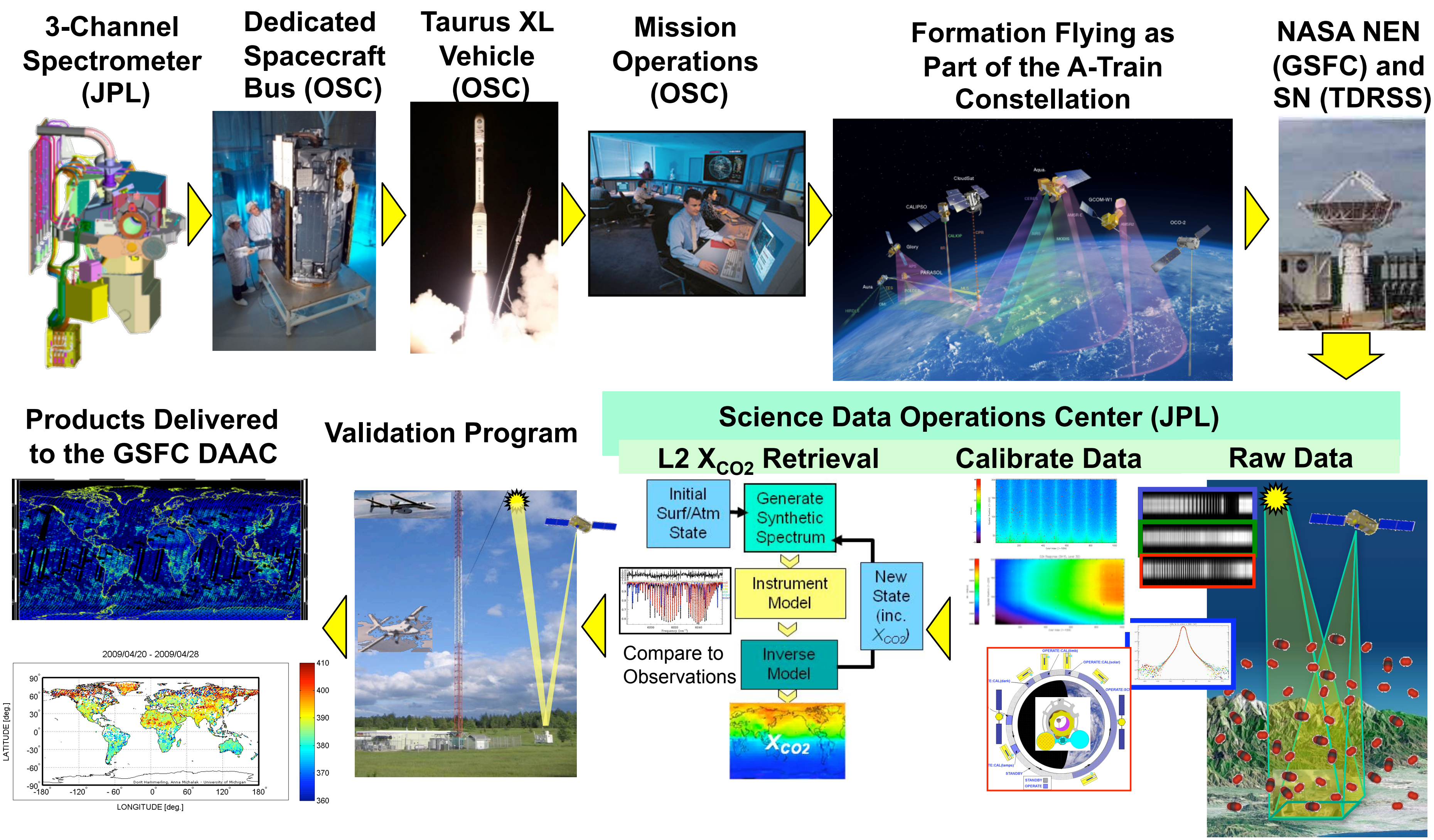
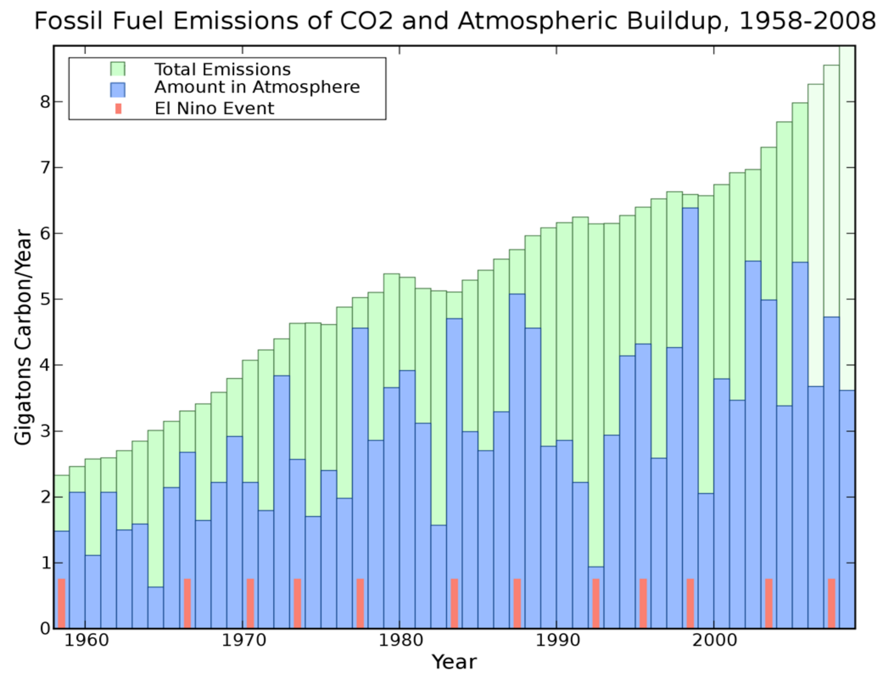


The Mystery of the Missing CO_2

- Humans have added >200 Gt C to the atmosphere since 1958
- Less than half of this CO_2 is staying in the atmosphere
- Where are the *sinks* that are absorbing over half of the CO_2?
  - Land or ocean?
  - Eurasia/North America?
- Why does the CO_2 buildup vary from year to year with nearly uniform emission rates?
- How will these CO_2 sinks respond to climate change?



?

The Need for High Precision

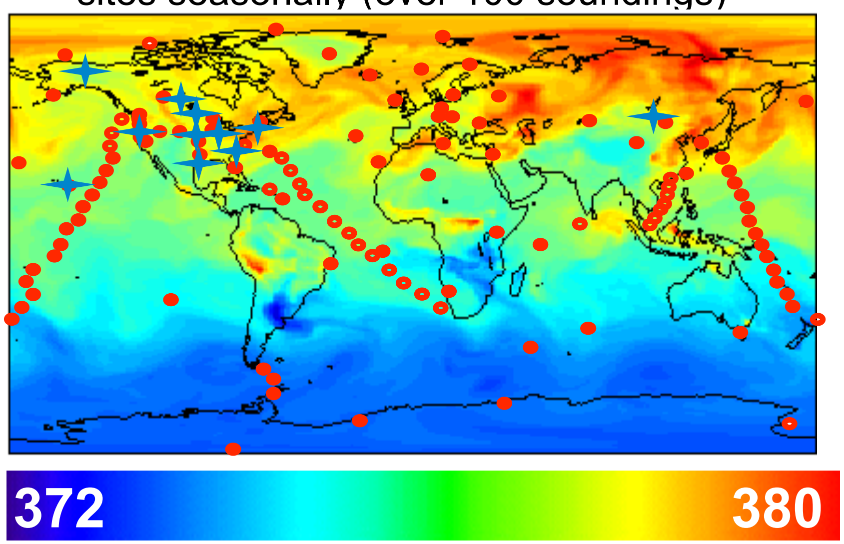
CO_2 sources and sinks must be inferred from spatial variations in the (>380 ppm) background CO_2 distribution

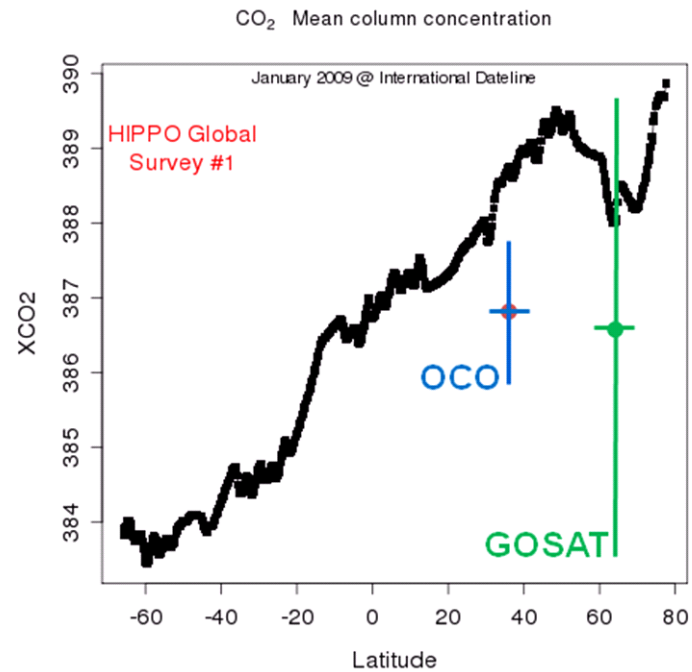
- Largest variations near surface

Space based NIR measurements constrain column averaged CO2, X_{CO2}

High precision is essential to resolve small (<2%) spatial variations in X_{CO2}

- OCO precision: <0.3% (1 ppm) verified at validation sites seasonally (over 100 soundings)



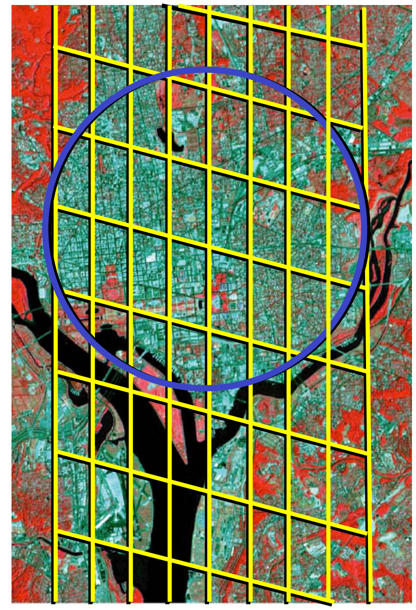


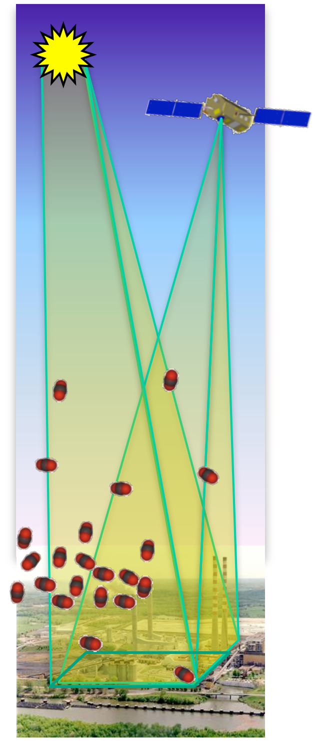
The nominal, regional scale X_{CO2} precision targets for the OCO and GOSAT instruments (blue and green, as indicated) are compared to the X_{CO2} cross-section measured by recent transects of the NSF HIAPER aircraft (S. Wofsy, private communication, 2009).

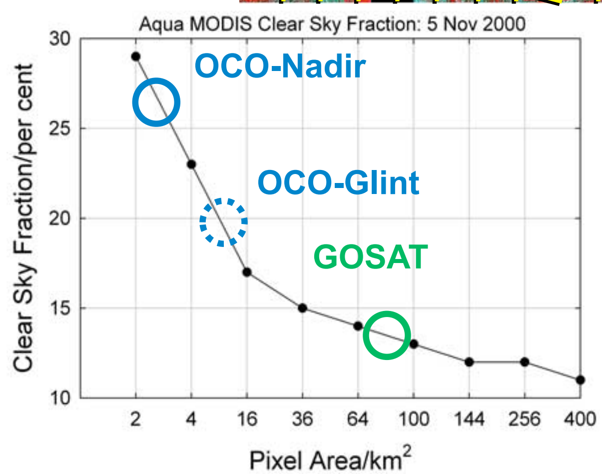
High Spatial Resolution Is Also Needed

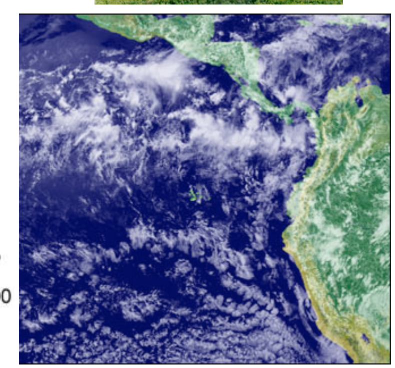
A small sounding footprint increases:

- Ability to record cloud free soundings in partially cloudy regions
  - Probability decreases with increasing optical path length and footprint area
  - Footprint 1.3km x 2.25km
- Ability to clearly discriminate discrete point sources
- Sensitivity to discrete CO_2 point sources
  - For a given precision (e.g. 1 ppm), detection limit (kg of CO_2) scales as 1/footprint area







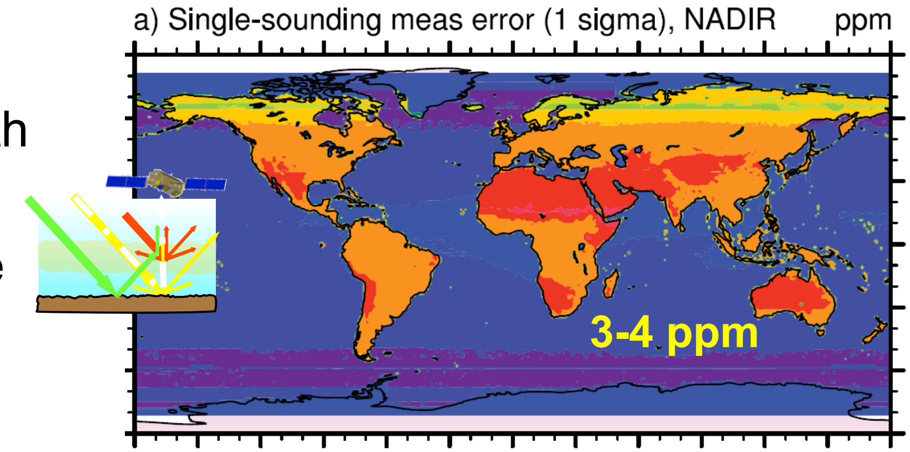


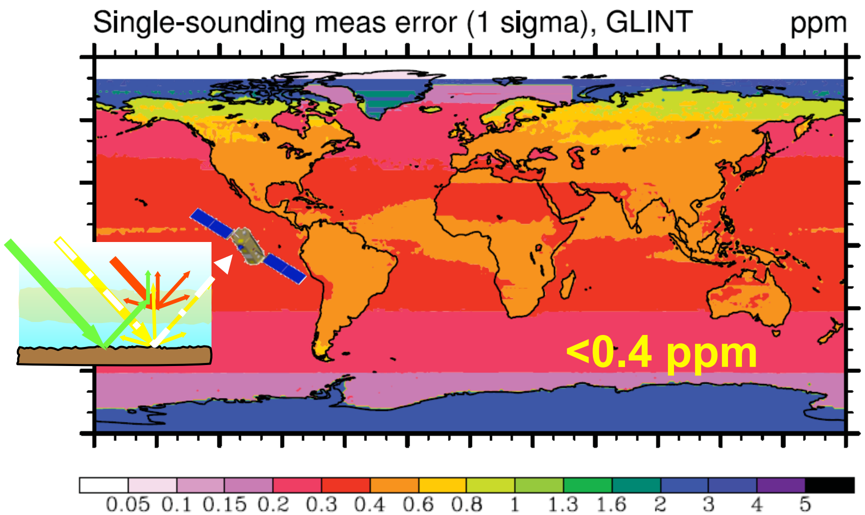
High SNR Coverage Needed over both Continents and Oceans

Full global coverage is needed to:

- Resolve sources and sinks over both land and ocean;
- Track air masses over the full range of latitudes, minimizing errors introduced as CO_2 is transported in an out of field of regard

- Nadir Observations:
  - More homogenous, cloud-free scenes over continents
  - Low Signal/Noise over dark surfaces
- Sun Glint observations
  - High signal/noise over dark ocean and ice covered surfaces
  - Somewhat more cloud interference





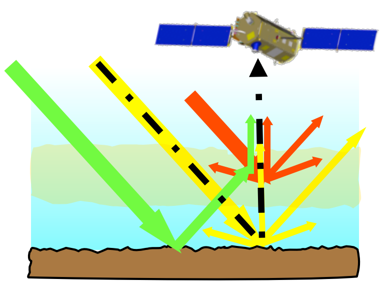
Single sounding random errors for nadir and glint [Baker et al. ACPD, 2008].

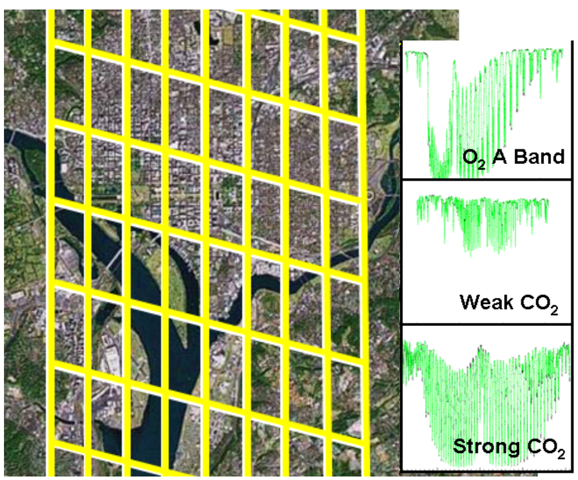
OCO-2 has Three Observation Modes

Nadir Observations:

+ Small footprint (< 3 km^2)

- Low Signal/Noise over dark surfaces (ocean, ice)

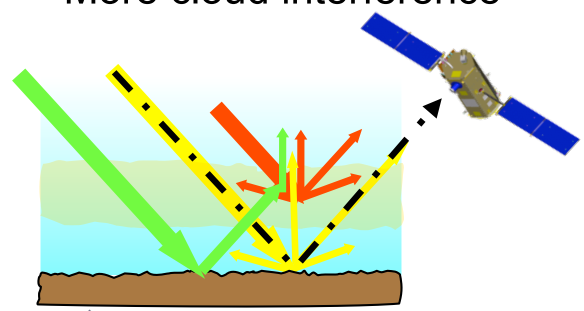


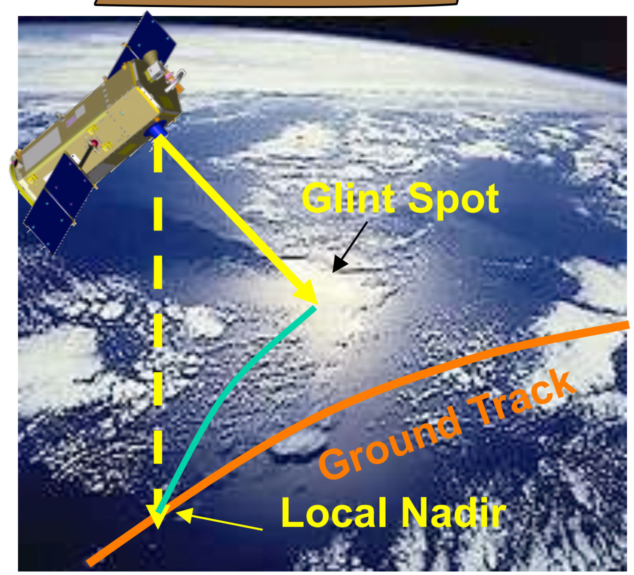


Glint Observations:

+ Improves Signal/Noise over oceans

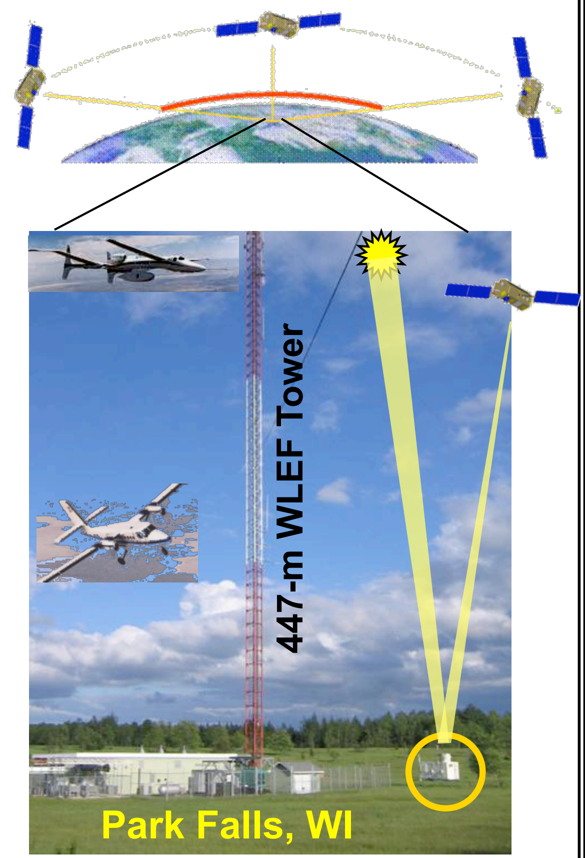
− More cloud interference





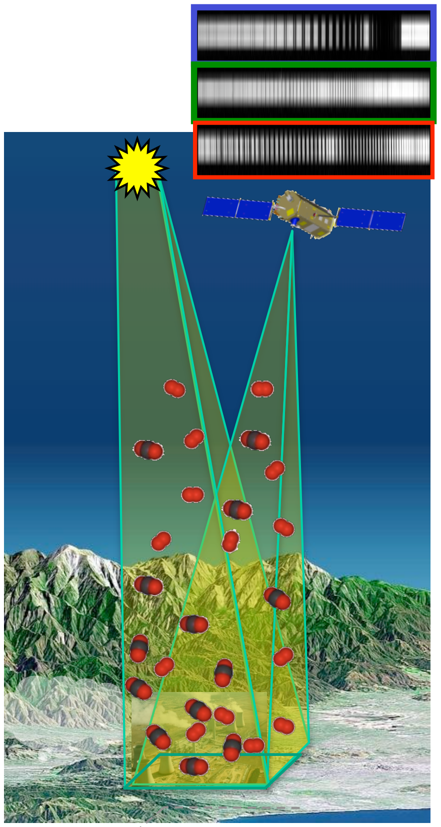
Target Observations:

- Validation over ground based FTS sites, field campaigns, other targets



Measurement Approach

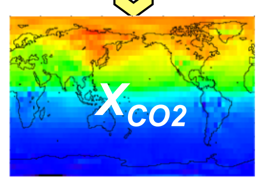
Collect spectra of CO_2 & O_2 absorption in reflected sunlight over the globe



Retrieve variations in the *column averaged CO_2 dry air mole fraction, X_{CO2}* over sunlit hemisphere

Initial Surf/Atm State → Generate Synthetic Spectrum → Instrument Model → Difference Spectra → Inverse Model → New State (inc. X_{CO2}) → Generate Synthetic Spectrum

Inverse Model → X_{CO2}



Validate measurements to ensure X_{CO2} precision of 1 - 2 ppm (0.3 - 0.5%)

The OCO-2 Mission Has Been Initiated

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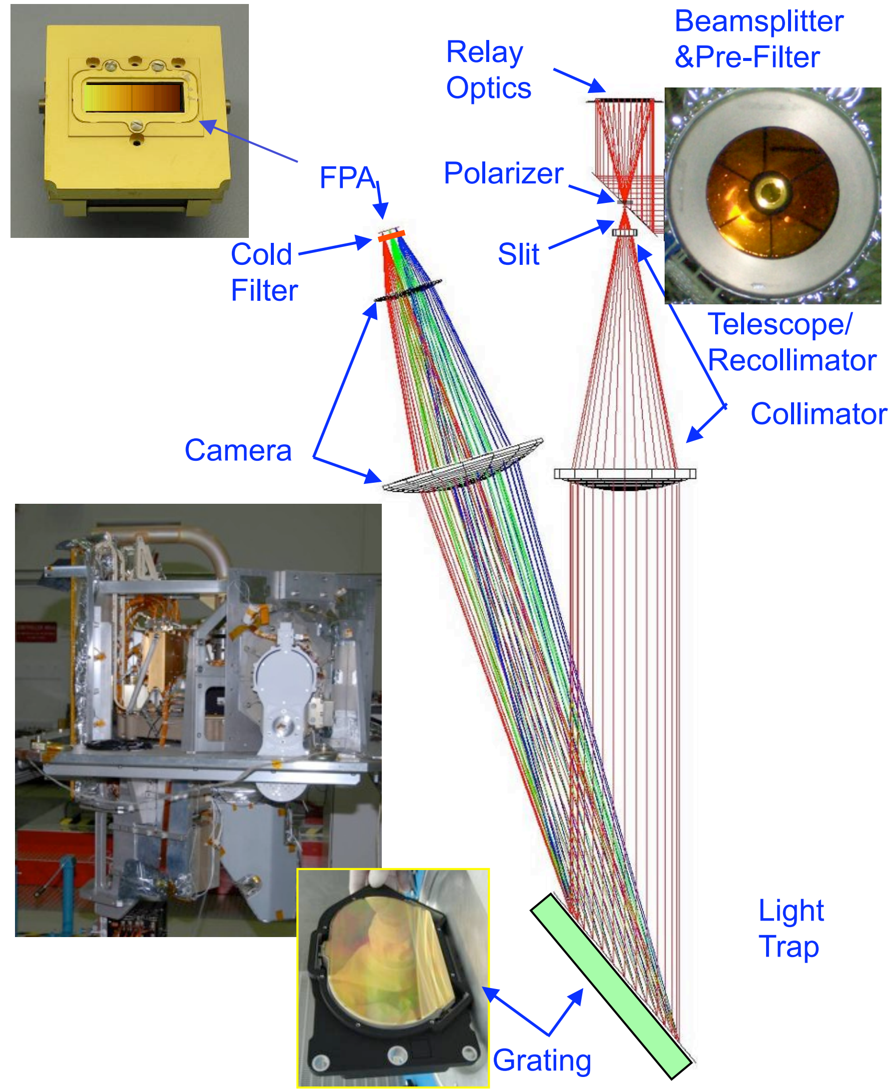
- December 2009: The U.S. Congress added funding to the NASA FY2010 budget to restart the OCO Mission
- February 2010: The President's 2011 NASA budget proposal included funding for a "Carbon Copy" of the OCO mission, now designated "OCO-2," with a launch date "no later than February 2013"
- The OCO-2 mission is currently in development
  - Instrument and spacecraft components are on order
  - The launch vehicle has been selected through a competitive process
  - A Critical Design Review was conducted on August 25-26, 2010
  - Key Decision Point –C meeting was held September 24, 2010
  - Mission Implementation Phase began on October 1, 2010
- Launch Date: February 2013

Same Instrument as OCO

- 3 co-bore-sighted, high resolution, imaging grating spectrometers
  - O_2 0.765 μm A-band
  - CO_2 1.61 μm band
  - CO_2 2.06 μm band
- Resolving Power > 20,000
- Optically fast: f/1.8 (high SNR)
- Swath: < 0.8° (10.6 km at nadir)
- 8 Footprints: 1.29 x 2.25 km @ nadir
- Mass: 140 kg
- Power: ~105 W
- **Changes from OCO**
  - New focal plane arrays (FPA) - Substrate removed HgCdTe FPA's
  - New cryocooler – NOAA GOES-R



Instrument on Track for Delivery by Mar 2012

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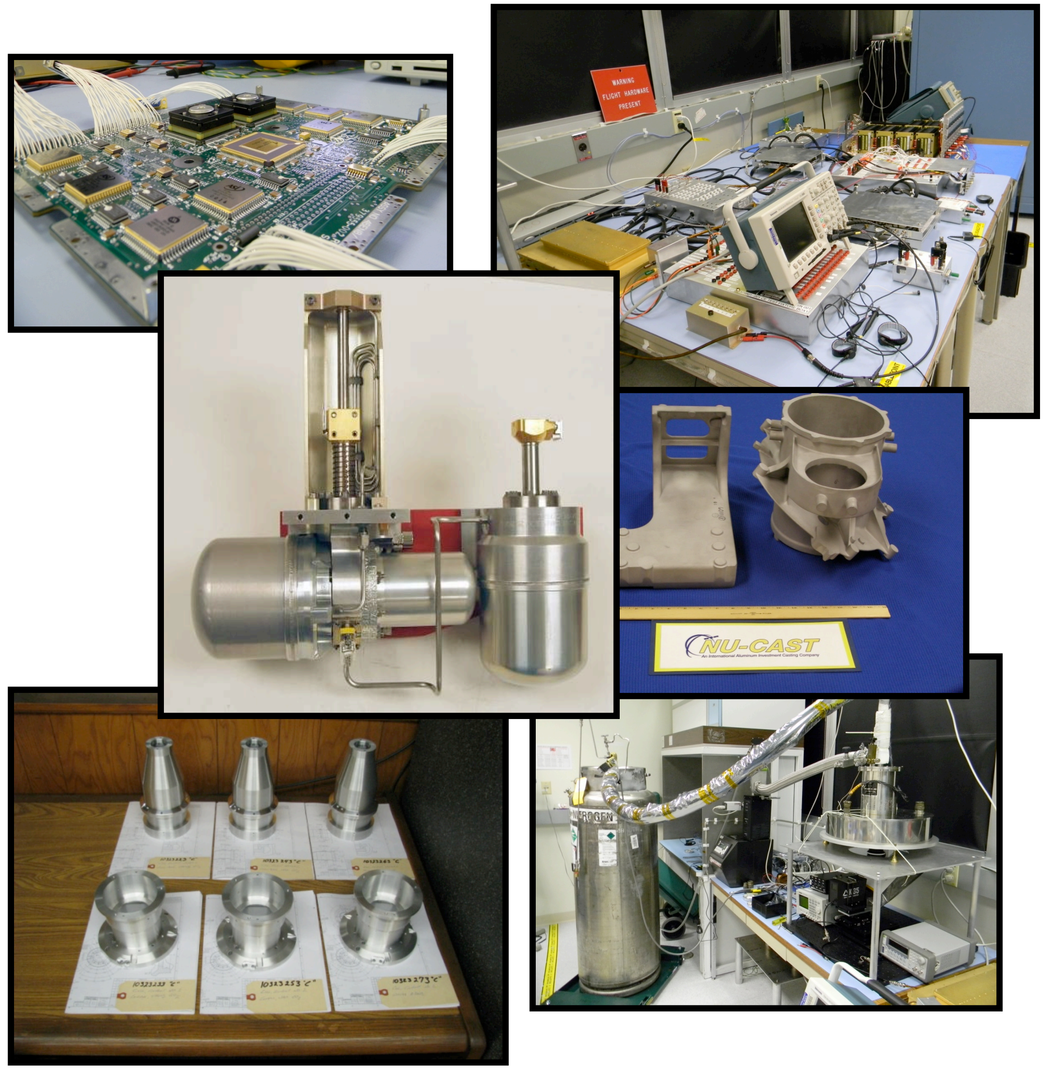
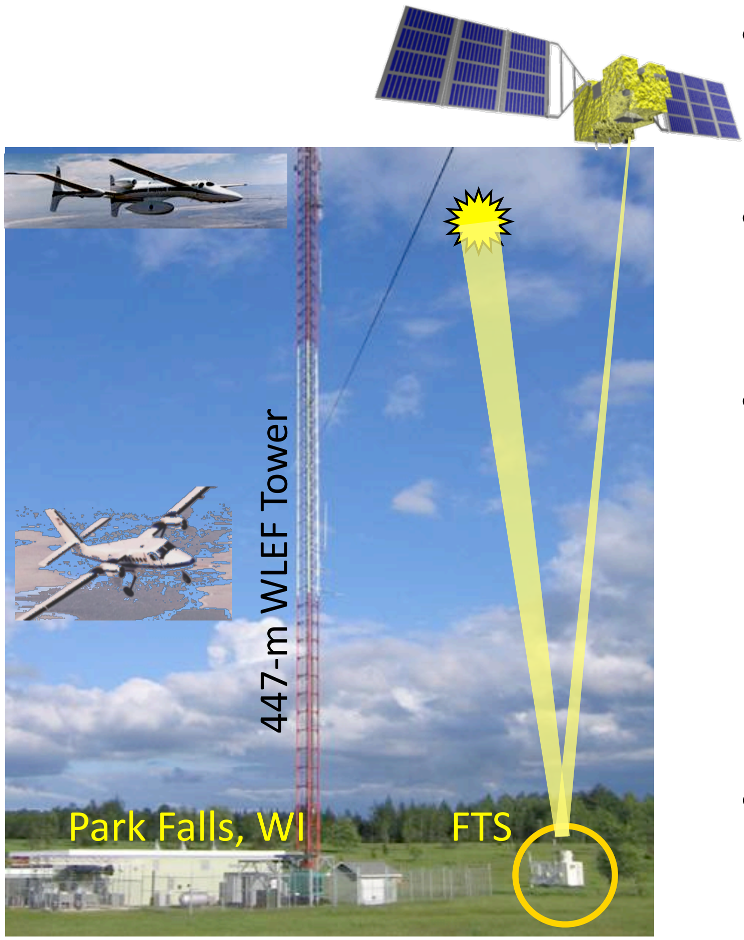
- Cryocooler – Existing NOAA GOES-R Series coolers are now in hand
- Electronics – EMs built; Flight model electronics are now being fabricated
- Mechanical – Castings and housings have been fabricated
- Thermal – The radiators have been delivered and the heat pipes are scheduled for delivery late this month
- Detectors – Standalone cold temperature tests have commenced



The ACOS Project: Processing and Validating X_{CO2} from GOSAT



- The Japanese GOSAT satellite is measuring over the same spectral region as OCO-2 with an FTS (TANSO-FTS)
- These measurements are being processed through the OCO-2 retrieval algorithm
- A critical element of the validation strategy was the Total Carbon Column Observing Network (TCCON)
  - High resolution FTS's measure the absorption of direct sunlight by CO_2 and O_2, in the same spectral regions used by the TANSO-FTS.
- We are now comparing the ACOS X_{CO2} from GOSAT measurements with the TCCON validation data.

Current (and Future) TCCON Sites

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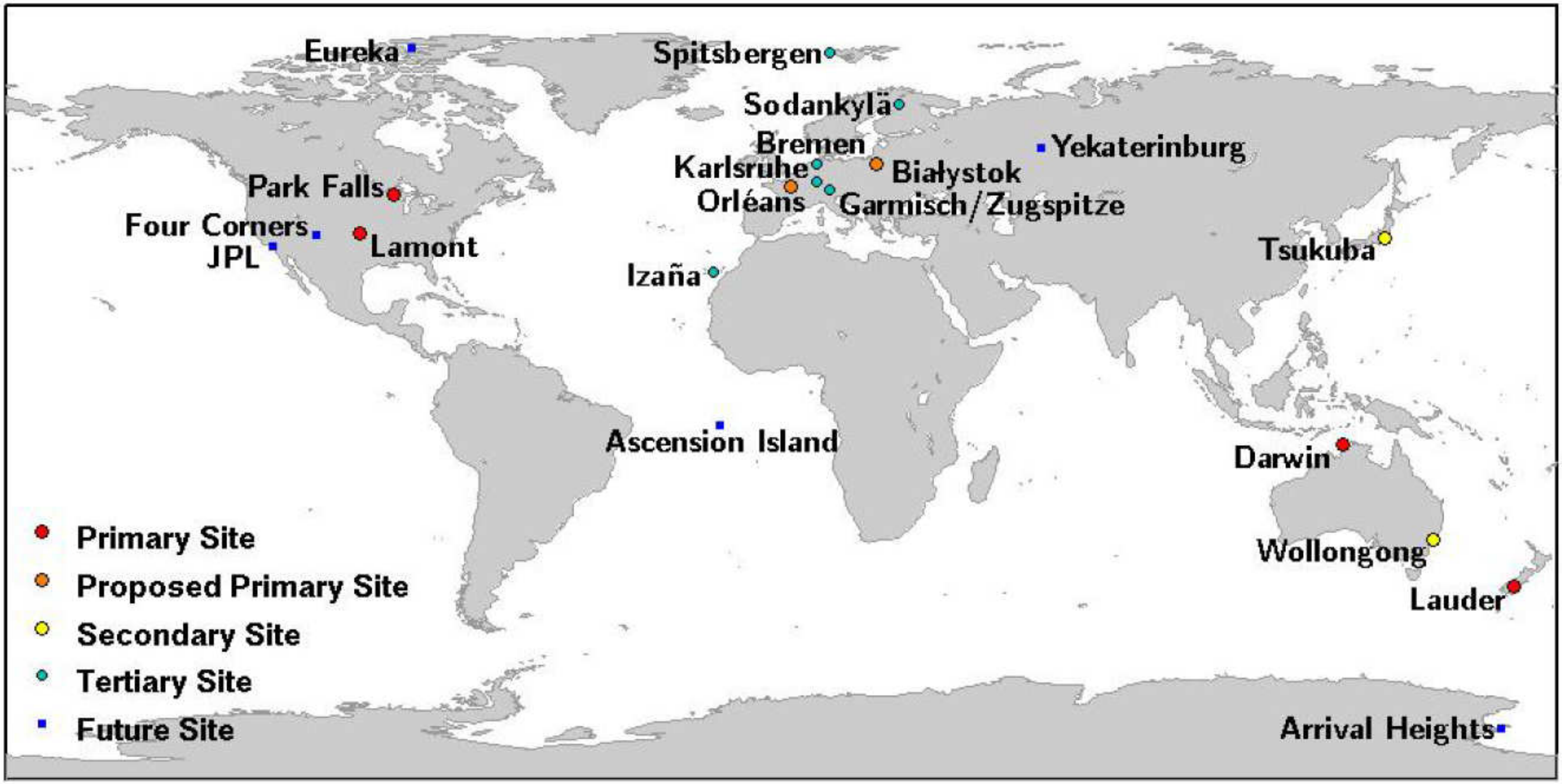
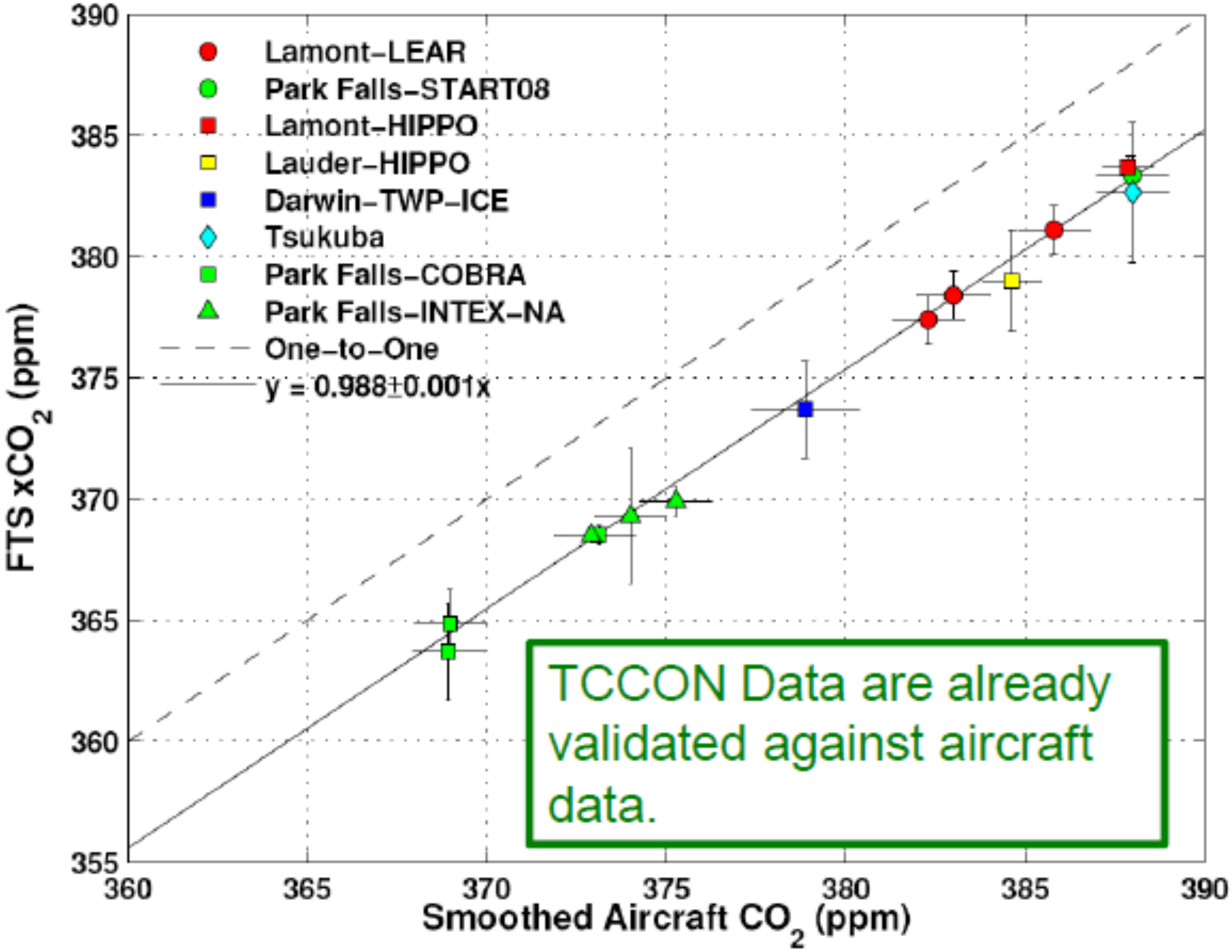
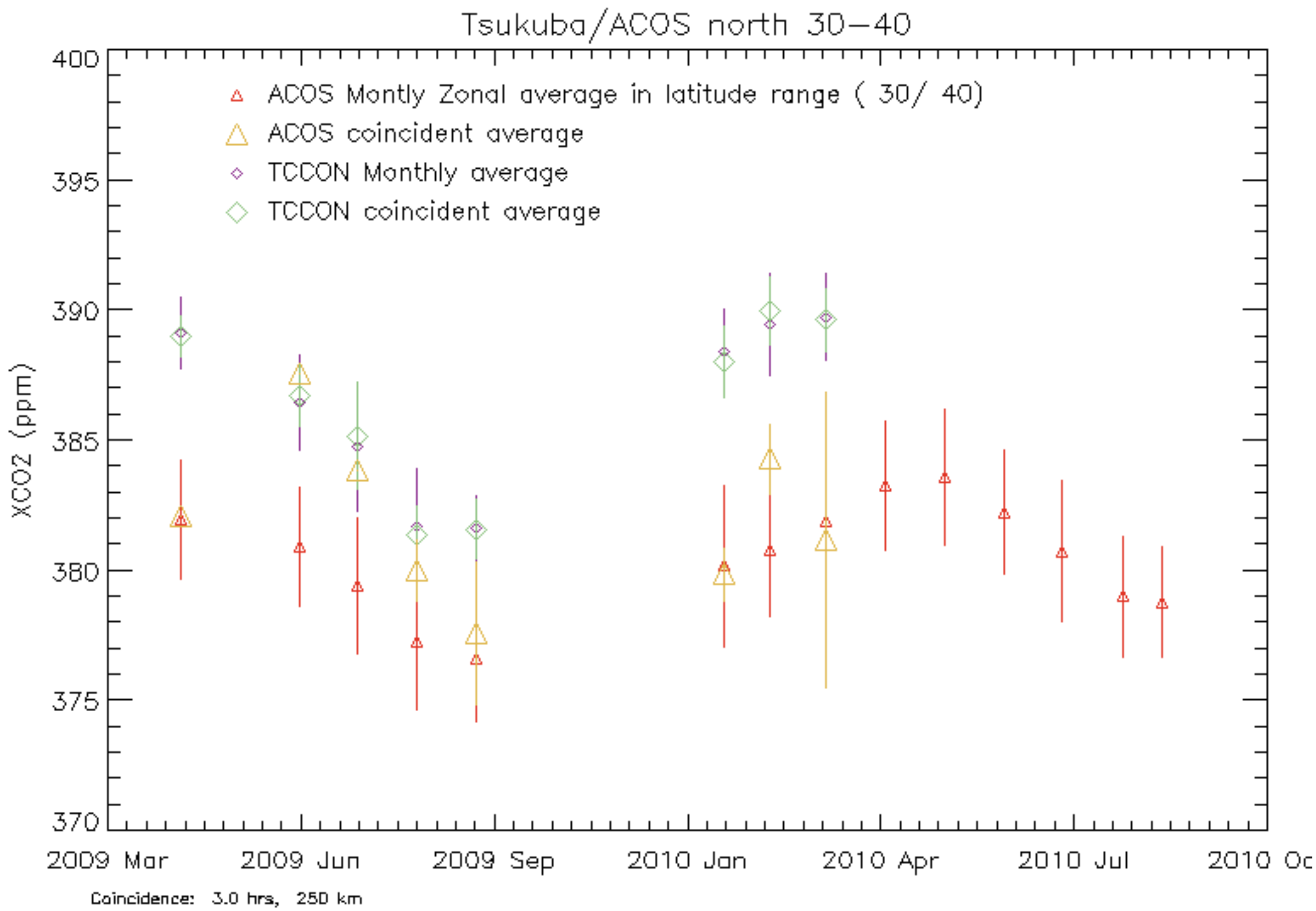


TCCON Measurements Validated Against Aircraft Observations



TCCON Data are already validated against aircraft data.

ACOS-GOSAT/TCCON Comparisons



- The current X_{CO2} retrievals have a (global) ~7 ppm (2%) low bias, when compared to bias-corrected TCCON data.
- Seasonal patterns are visible in ACOS data

Screened ACOS-GOSAT L2 Products for April 2010

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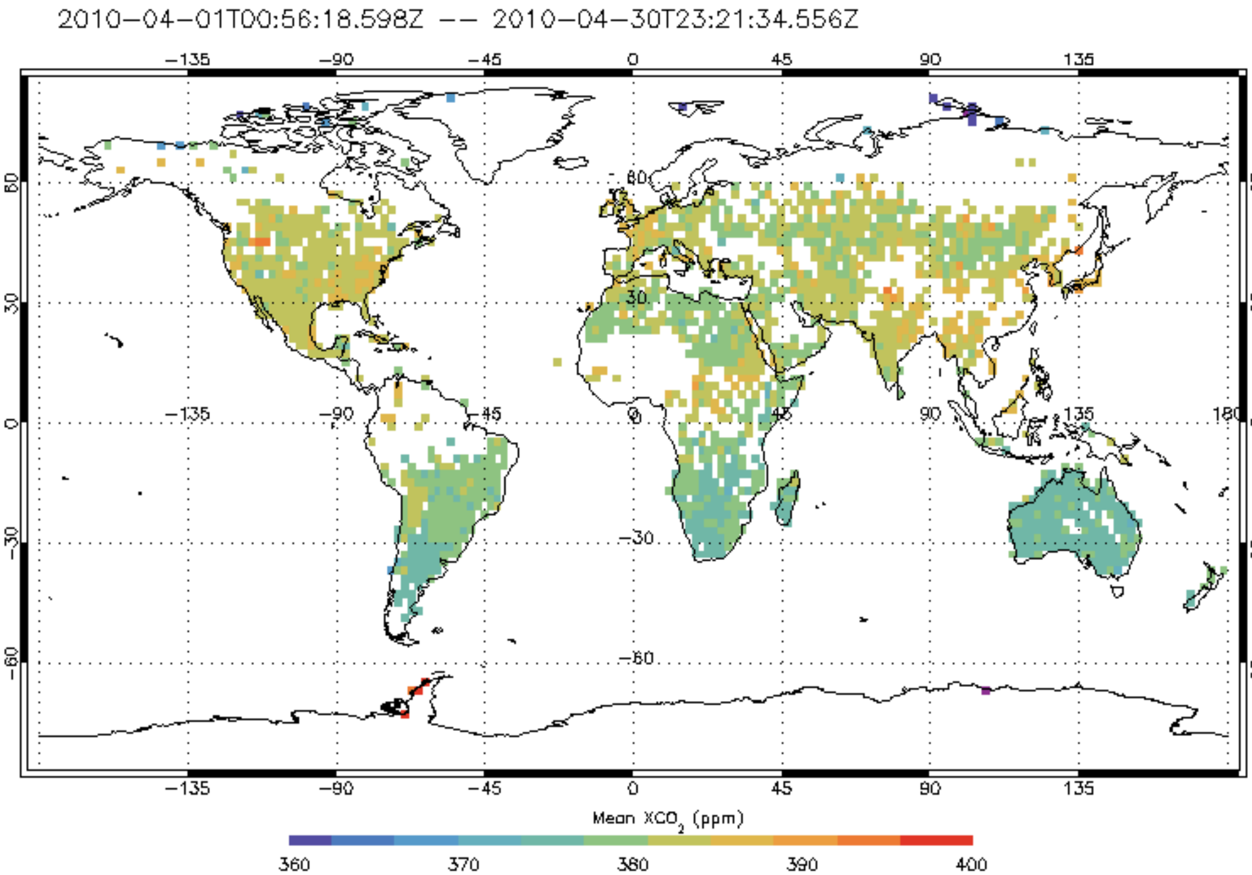

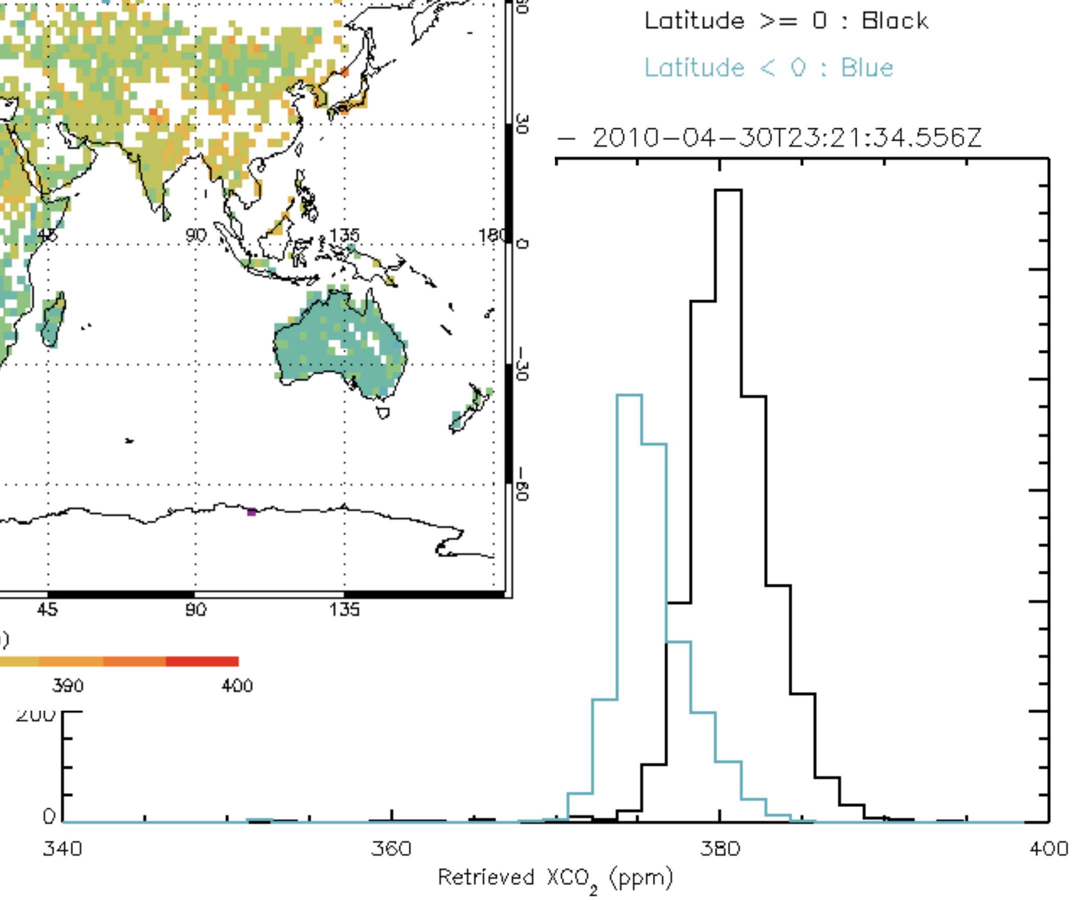

Springtime North to South gradient clearly seen.

Screened ACOS-GOSAT L2 Products for July 2010

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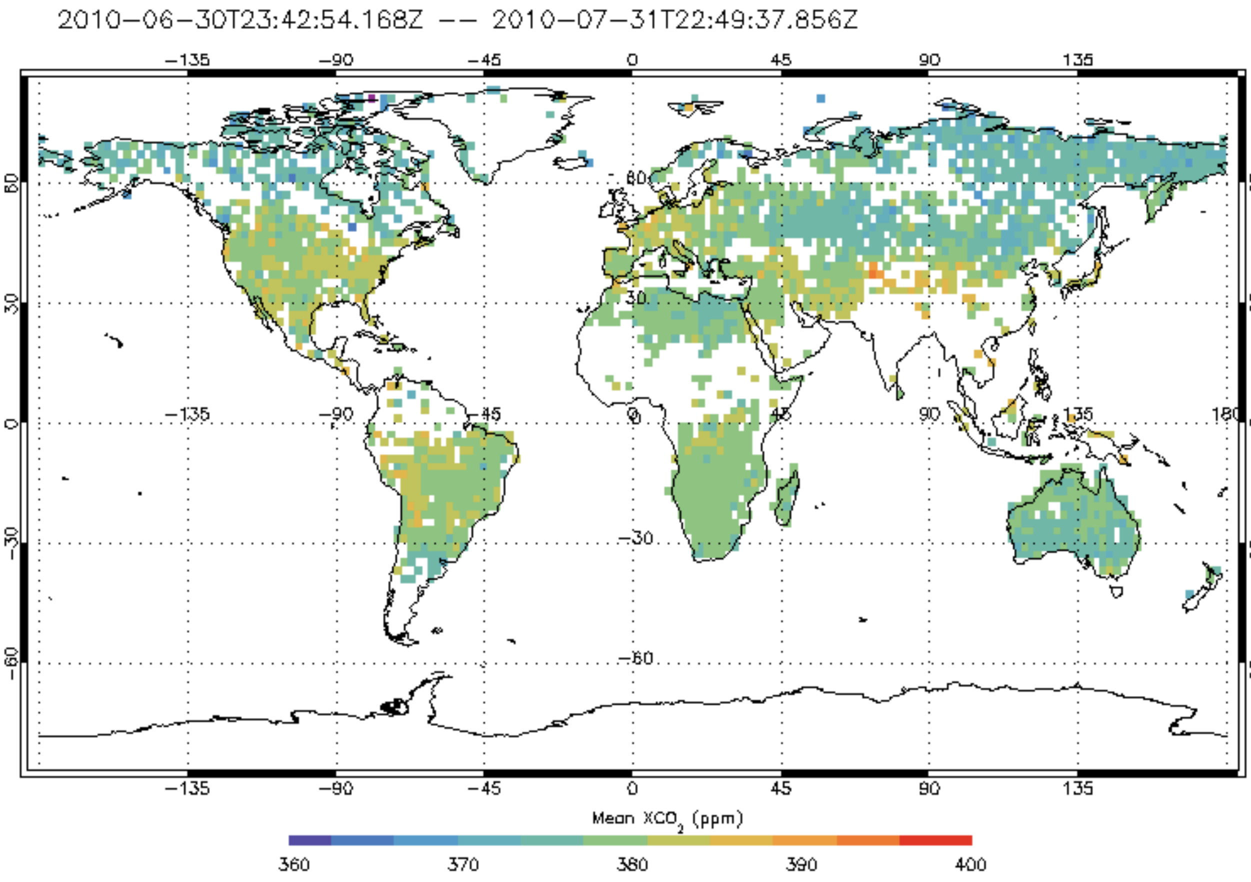

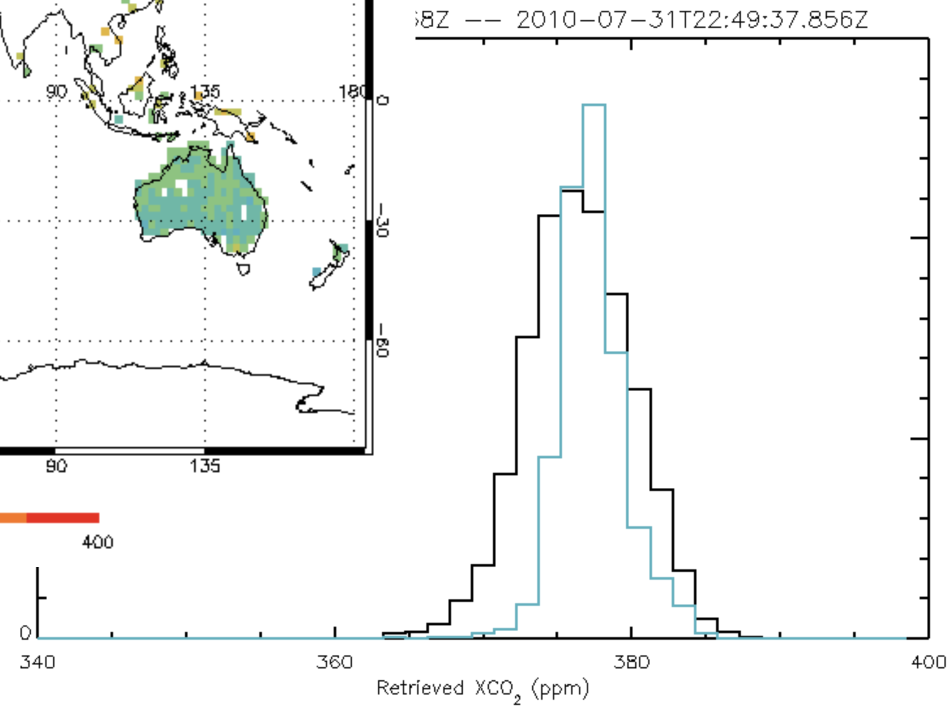

Gradient not seen in summer.

Conclusions

- Accurate and precise measurements of carbon dioxide sources and sinks is of paramount importance.
- Despite progress, our knowledge is limited by the lack of high precision global measurements of atmospheric carbon dioxide.
- While there have been advances in space-based measurements there is no existing or confirmed sensor capable of quantifying carbon dioxide sources and sinks.
- The OCO-2 instrument is being built, and the OCO-2 algorithm is being tested and refined, thanks to the availability of the GOSAT data.
- OCO-2 will collect up to 1,000,000 (10^6) soundings over the sunlit hemisphere each day.
- Verified sounding precision of 1 ppm (< 0.3% of 385 ppm background) as per level 1 requirements.
- The ACOS/SDOS team is now routinely generating L2 products
  - Data became available through the Goddard DAAC last week.
  - The X_{CO2} retrievals currently have a global bias of ~ 7 ppm (2%)
    - Most of the bias is associated with a ~10 hPa high surface pressure offset

OCO-2 Overview

The Orbiting Carbon Observatory - 2 (OCO-2)

Watching The Earth Breathe…Mapping CO2 From Space

Salient Features:
Category 2 mission per NPR 7120.5D
Risk class C per NPR 8705.4
High-resolution, three-channel grating spectrometer (JPL)
Partnership with OSC (Spacecraft)
High heritage spacecraft, flies in formation with the A-Train
Launch: February 2013 on Taurus XL 3110 from Vandenberg AFB
Operational life: 2 years
Science Team Leader: Dr. David Crisp
Project Scientist: Dr. Michael Gunson, Deputy: Dr. Annmarie Eldering
Project Manager: Dr. Ralph Basilio, Deputy (acting): Said Kaki
Earth Science Flight Projects Office Manager: Dr. Steven Bard
ESSP Acting Program Manager: Greg Stover, LaRC, Mission Manager: James Wells, LaRC
Program Scientist: Dr. Kenneth Jucks, NASA HQ
Program Executive: Eric Ianson, NASA HQ

Mission Science Objective: Collect the first space-based global measurements of atmospheric CO_2 with the precision, resolution, and coverage needed to characterize its sources and sinks on regional scales and quantify their variability over the seasonal cycle .

Key Science Products: Retrieve estimates of the column-averaged CO_2 dry air mole fraction (X_{CO2}) on regional scales (≥ 1000 km) from space-based measurements of the absorption of reflected sunlight by atmospheric CO_2 and O_2, collected in cloud-free scenes over ≥80% of range of latitudes on the sunlit hemisphere at monthly intervals for 2 years.